growth can not profitably be renewed until an interval of some years has elapsed.

Again it is well known that when a plant is sown upon land which has not carried that particular crop for many years beforehand it starts into growth with a vigor it rarely displays upon land where it forms an item in the regular rotation, even though the new land is so impoverished that the final yield is indifferent. In the instance quoted above, where swedes were sown on Little Hoos field, Rothamsted, after a very long interval, although the yield was poor on the unmanured plots, yet the seeds germinated and made their early growth in a very remarkable fashion, incomparably better than did the same seed sown upon adjoining land in a high state of fertility, but which had been cropped with swedes from time to time previously. There is thus some positive evidence that most plants—some to a very slight degree, like wheat and mangolds, others markedly, like clover, turnips, and flax—effect some change in the soil which unfits it for the renewed growth of the crop. The injurious action may even arise from the growth of a different crop, as in the well-known experiments at the Woburn Fruit Farm, where Pickering has shown that the roots of grasses exert a positively injurious effect, distinct from competition for food, water or air, upon fruit trees growing in the same soil.

Assuming that the persistence in the soil of obscure diseases appropriate to the particular plant can be neglected as the cause of these phenomena, there still remains some unexplained factor arising from a plant's growth which is injurious to a succeeding crop, and this may either be the excreted toxins of Whitney's theory or may be some secondary effects due to the competition of injurious products of the bacteria and other microflora accumulating in the particular soil layer in which the roots of the crop chiefly reside.

Experimental evidence is as yet wanting as to these highly complex interactions between the higher plants and the microflora of the soil, but Russell and other observers have shown how greatly a disturbance of the normal equilibrium of the flora of the soil may affect its fertility, as measured by the yield of a higher plant. Partial sterilization, such as is brought about by heating the soil to 98° for ten hours, will double the yield of the succeeding crop and will show a perceptible beneficial effect up to the fourth crop after the heating, and exposure to the vapors of volatile antiseptics like toluene or carbon bisulphide, which are afterwards entirely removed by exposure, will increase the yield in a similar but smaller degree; even drying the soil appears to have an influence upon its fertility.

It is in this direction, perhaps, that the clue may be found to the unexplained benefits of the rotation of crops, and to some of the other facts difficult of explanation upon the ordinary theories of plant nutrition, which have been advanced by Whitney and his co-workers. The soil, however, is such a complex medium—the seat of so many and diverse interactions, chemical, physical and biological—and is so unsusceptible of synthetic reproduction from known materials, that experimental work of a crucial character becomes extremely difficult and above all requires to be interpreted with extreme caution and conservatism.

A. D. Hall
Rothamsted Experiment Station

THE DUBLIN MEETING OF THE BRITISH ASSOCIATION—II.

The Metabolism of the Plant Considered as a Catalytic Reaction[1]

After outlining the three fundamental principles of reaction-velocity, the law of

[1] Address by Professor F. F. Blackman, M.A., F.R.S., president of the botanical section, on "The Manifestations of the Principles of Chemical Mechanics in the Living Plant."

mass, and the catalytic acceleration of reaction velocity, Professor Blackman proceeded to consider the broad phenomena of metabolism or chemical change in the living organism from the point of view of these principles of chemical mechanics.

Plants of all grades of morphological complexity, from bacteria to dicotyledons, have this in common, that throughout their active life they are continually growing. Putting aside the *qualitative* distribution of growth that determines the morphological form, as a stratum of phenomena above the fundamental one that we are about to discuss, we find that this growth consists in the assimilation of dead food-constituents by the protoplasm, with a resulting increase in the living protoplasm accompanied by the continual new formation of dead constituents, gaseous CO_2, liquid water, solid cellulose, and what not. This continual flux of anabolism and katabolism is the essential character of metabolism, but withal the protoplasm increases in amount by the excess of anabolism over katabolism.

Protoplasm has essentially the same chemical composition everywhere, and in the whole range of green plants the same food materials seem to be required; the six elements of which proteids are built are obviously essential in quantity as building material, but in addition small amounts of Fe, Ca, K, Mg, Na, Cl and Si are in some other way equally essential. What part these secondary elements play is still largely a matter of hypothesis.

Regarding metabolism thus crudely as if it were merely a congeries of slow chemical reactions, let us see how far it conforms to the laws of chemical mechanics we have outlined.

If the supply of any one of these essential elements comes to an end, growth simply ceases and the plant remains stationary, half-developed. If a *Tropæolum* in a pot be watered with dilute salt-solution, its stomata soon close permanently, and no CO_2 can diffuse in to supply the carbon for further growth of the plant. In such a condition the plant may remain for weeks looking quite healthy, but its growth may be quite in abeyance.

In agricultural experience, in manuring the soil with nitrogen and the essential secondary elements, the same phenomenon is observed when there is a shortage of any single element. If a continuous though inadequate supply of some one element is available, then the crop development is limited to the amount of growth corresponding to this supply. Agriculturalists have formulated the "law of the minimum," which states that the crop developed is limited by the element which is minimal, *i. e.*, most in deficit. Development arrested by "nitrogen-hunger" is perhaps the commonest form of this. All this is, of course, in accordance with expectation on physical-chemical principles. The quantity of anabolic reaction taking place should be proportional to the amount of actively reacting substances present, and if any one essential substance is quite absent the whole reaction must cease. It therefore seems clouding a simple issue and misleading to say of a plant which, from the arrested development of nitrogen-hunger, starts growth again when newly supplied with nitrogen that this new growth is a response to a "*nitrogen stimulus.*" It would appear rather to be only the removal of a limiting condition.

Let us now move on a stage. Suppose a growing plant be liberally supplied with all the thirteen elements that it requires, what, then, will limit its rate of growth? Fairy bean-stalks that grow to the heavens in a night elude the modern investigator, though some hope soon to bring back that golden age with overhead electric wires and underground bacterial inoculations. If

everything is supplied, the metabolism should now go on at its highest level, and quantities of carbon, nitrogen, hydrogen and oxygen supplied as CO_2, nitrates and water will interact so that these elements become converted into proteid, cellulose, etc. Now this complex reaction of metabolism only takes place in the presence of protoplasm, and a small amount of protoplasm is capable of carrying out a considerable amount of metabolic change, remaining itself undestroyed. We are thus led to formulate the idea that metabolism is essentially a catalytic process. In support of this we know that many of the inherent parts of the protoplasmic complex are catalytic enzymes, for these can be separated out of the protoplasm, often simply by high mechanical pressure. We know, too, nowadays that the same enzymes that accelerate katabolic processes also accelerate the reverse anabolic processes.

In time a small mass of protoplasm will, while remaining itself unchanged, convert many times its own weight of carbon from, let us say, the formaldehyde (HCHO) of photosynthesis to the carbon dioxide (CO_2) of respiration.

If metabolism is a complex of up-grade and down-grade changes catalyzed by protoplasm we must expect the amount of metabolism to obey the law of mass and to be proportional to the masses of substances entering into the reaction. The case when any one essential element is a limiting factor we have already considered. When all are in excess, then the *amount of the catalyst present* becomes in its turn the limiting factor. Transferring this point of view to the growing plant, we expect to find the limited mass of protoplasm and its constituent catalysts setting a limit to the rate of metabolic change in the extreme case where all the materials entering into the reaction are in excess. When once this supply is available further increase in supplies can not be expected to accelerate the rate of growth and metabolism beyond the limit set by the mass of protoplasm. This, of course, is in accordance with common experience. The clearest experimental evidence is in connection with respiration and the supply of carbohydrates—this, no doubt, because the carbohydrate material oxidized in respiration is normally stored inside plant-cells in quantity and can be estimated. When the supplies for an internal process have to be obtained from outside, then we have the complications of absorption and translocation to obscure the issue, especially in the case of a higher plant.

Let us first take a case where the carbohydrate supply is in excess and the amount of catalytic protoplasm is small and increasing. Thus it is in seeds germinating in the dark: respiration increases day by day for a time, though carbohydrate reserves are steadily decreasing. Palladine[2] has investigated germinating wheat by analyzing the seedlings and determining the increase of the essential (non-digestible) proteids day by day. The amount of these proteids he regards as a measure of the amount of actual protoplasm present. Assuming this to be so, he finds an approximately constant ratio between the amount of protoplasm at any stage and the respiration.

As germination progresses in the dark the supplies of reserve carbohydrate presently fail, and then the respiration no longer increases in spite of the abundant protoplasm. According to our thesis the catalyst is now in excess and the CO_2 production is limited by the shortage of respirable material.

This second type was more completely investigated by Miss Matthæi and myself in working on the respiration of cut leaves of cherry-laurel kept starved in

[2] *Revue gén. de botanique,* Tome VIII., 1896.

the dark. For a time the CO_2 production of these non-growing structures remains uniform, and then it begins to fall off in a logarithmic curve. We interpret both phenomena in the same way: in the initial level phase the respirable material in the leaf is in excess, and the amount of catalytic protoplasm limits the respiration to the normal biological level; in the second falling phase some supply of material is being exhausted, and we get a logarithmic curve controlled by the law of mass, as much, it would seem, as when cane-sugar is hydrolyzed in aqueous solution.

After these two illustrations of the action of the law of mass from the more simple case of respiration we return to the consideration of the totality of metabolic reactions as exemplified in growth.

What should we expect to be the ideal course of growth, that is, the increase of the mass of the plant regarded as a complex of reactions catalyzed by protoplasm? Let us consider, first, the simplest possible case, that of a bacterium growing normally in a rich culture solution. When its mass has increased by anabolism of the food material of the culture medium to a certain amount, it divides into two. As all the individuals are alike; counting them would take the place of weighing their mass. The simplest expectation would be that, under uniform conditions, growth and division would succeed each other with monotonous regularity, and so the number or mass of bacteria present would double itself every n minutes. This may be accepted as the ideal condition.

The following actual experiment may be quoted to show that for a time the ideal rate of growth is maintained, and that at the end of every n minutes there is a doubled amount of protoplasm capable of catalyzing a doubled amount of chemical change and carrying on a doubled growth and development.

From a culture of *Bacillus typhosus* in broth at 37° C. five small samples were withdrawn at intervals of an hour, and the number of bacteria per unit volume determined by the usual procedure. The number of organisms per drop increased in the following series: 6.7, 14.4, 33.1, 70.1, 161.0.[3] This shows a doubling of the mass of bacteria in every fifty-four minutes and actually represents a strictly logarithmic curve.

We may quote some observations made by E. Buchner[4] of the rate at which bacteria increase in culture media. Bacillus coli communis was grown at 37° C. for two to five hours, and by comparison of the initial and final numbers of bacteria the time required for doubling the mass was calculated. Out of twenty-seven similar experiments a few were erratic, but in twenty cases the time for doubling was between 19.4 and 24.8 minutes, giving a mean of 22 minutes. This produces an increase from 170 to 288,000 in four hours. No possible culture medium will provide for prolonged multiplication of bacteria at these rates.

Cohn[5] states that if division takes place every sixteen minutes, then in twenty-four hours a single bacterium 1 μ long will be represented by a multitude so large that it requires twenty-eight figures to express it, and placed end to end they would stretch so far that a ray of light to travel from one end to the other would take 100,000 years. The potentialities of protoplasmic catalysis are thus made clear, but the actualities are speedily cut short by limiting factors.

[3] For this unpublished experiment on bacterial growth I am indebted to Miss Lane-Claypon, of the Lister Institute of Preventive Medicine.

[4] Buchner, *Zuwachsgrossen u. Wachsthumsgeschwindigkeiten*, Leipzig, 1901.

[5] Cohn, *Die Pflanze*, Breslau, 1882, p. 438.

For a while, however, this ideal rate of growth is maintained. At the end of every n minutes there is a doubled amount of protoplasm present, and this will be capable of catalyzing twice the amount of chemical change and carrying on a doubled amount of growth and development. This is what common sense and the law of mass alike indicate, and is exactly what the logarithmic curve expresses.

This increase of the amount of catalytic protoplasm by its own catalytic activity is an interesting phenomenon. In Section K we call it growth, attribute it to a specific power of protoplasm for assimilation (in the strict sense), and leave it alone as a fundamental phenomenon, but are much concerned as to the distribution of the new growth in innumerable specifically distinct forms. In the chemical section they call this class of phenomenon "autocatalysis," and a number of cases of it are known. In these a chemical reaction gives rise to some substance which happens to catalyze the particular reaction itself, so that it goes on and on with ever-increasing velocity. Thus, we said that free acid was a catalyst to the hydrolysis of cane-sugar; suppose now that free acid were one of the products of the hydrolysis of sugar, then the catalyst would continually increase in amount in the test-tube, and the reaction would go faster and faster. Under certain conditions this actually happens. Again, when methyl acetate is hydrolyzed we normally get methyl alcohol and free acetic acid. This free acid acts as a catalyst to the hydrolysis, and the rate of change continually accelerates. Here, if the supply of methyl acetate were kept up by constant additions, the reaction would go faster and faster with a logarithmic acceleration.

For a clear manifestation of this autocatalytic increase in the plant it is, of course, essential that the supply of food materials to the protoplasm be adequate.

ACCELERATION OF REACTION-VELOCITY BY TEMPERATURE

We now turn to consider the fourth and last of the principles of chemical mechanics which we might expect to find manifested in metabolism.

It is a universal rule that rise of temperature quickens the rate at which a chemical reaction proceeds. Of course in some rare conditions this may not be obvious, but be obscured by superposed secondary causes; but almost always this effect is very clearly marked.

Further, the nature of the acceleration is a peculiar one. Rise of temperature affects nearly all physical and chemical properties, but none of these is so greatly affected by temperature as is the velocity of chemical reaction. For a rise of 10° C. the rate of a reaction is generally increased two or three fold, and this has been generalized into a rule by van't Hoff. As this increase is repeated for each successive rise of 10° C. either by the same factor or a somewhat smaller one, the acceleration of reaction-velocity by temperature is logarithmic in nature, and the curve representing it rises ever more and more steeply. Thus keeping within the vital range of temperature a reaction with a temperature factor of $\times 2$ per 10° C. will go sixteen times as fast at 40° C. as at 0° C., while one with a factor of $\times 3$ will go eighty-one times as fast.

This general law of the acceleration of reactions by temperature holds equally for reactions which are being accelerated by the presence of catalysts. As we regard the catalyst as merely providing for the particular reaction it catalyzes, a quick way round to the final stage by passing through the intermediate stage of forming a temporary addition-compound with the catalyst itself, so we should expect rise of temperature to accelerate similarly these substituted chemical reactions.

If this acceleration is a fundamental

principle of chemical mechanics it is quite impossible to see how vital chemistry can fail to exhibit it also.

ACCELERATION OF VITAL PROCESSES BY TEMPERATURE

At present we have but a small number of available data among plants to consider critically from this point of view. But all the serious data with which I am acquainted, which deal with vital processes that are to be considered as part of the protoplasmic catalytic congeries, do exhibit this acceleration of reaction-velocity by temperature as a primary effect.[6]

Let us briefly consider these data. On the katabolic side of metabolism we have the respiratory production of CO_2, and opposed to it on the anabolic side the intake of carbon in assimilation.

As a measure of the rate of the metabolic processes constituting growth we have data upon the division of flagellates; and finally there is the obscure process of circulation of protoplasm.

The intensity of CO_2 production is often held to be a measure of the general intensity of metabolism, but any relation between growth-rate and respiration has yet to be clearly established. Our science is not yet in the stage when quantitative work in relation to conditions is at all abundant; we are but just emerging from the stage that chemistry was in before the dawn of physical chemistry.

Taken by itself the CO_2-production of an ordinary green plant shows a very close relation with temperature. In the case of the cherry-laurel worked out by Miss Matthæi and myself the respiration of cut leaves rises by a factor of 2.1 for every 10° C. This has been investigated over the range of temperatures from 16° C. to 45° C. At this higher temperature the leaves can only survive ten hours in the dark, and their respiration is affected in quite a short time, but in the initial phases the CO_2 output has the value of .0210 gr. per hour and unit weight of leaf, while at 16°.2 C. the amount is only .0025 gr. CO_2. Thus the respiration increases over a range of tenfold with perfect regularity solely by increase of temperature. No reaction in a test-tube could show less autonomy. At temperatures above 45° C. the temperature still sooner proves fatal unless the leaf is illuminated so as to carry out a certain amount of photosynthesis and compensate for the loss of carbon in respiration. Thus, with rising temperature, there is at no time any sign of an optimum or of a decrease of the intensity of the *initial* stage of respiration.

Here, then, on the katabolic side of metabolism we have no grounds for assuming that "temperature-stimuli" are at work regulating the intensity of protoplasmic respiration, but we find what I can only regard as a purely physical-chemical effect. The numbers obtained by Clausen[7] for the respiration of seedlings and buds at different temperatures indicate a temperature coefficient of about 2.5 for a rise of 10° C.

To this final process of katabolism there could be no greater contrast than the first step of anabolism, the assimilation of carbon by the protoplasm as a result of photosynthesis. We must, therefore, next inquire what is the relation of this process to temperature.

This question is not so simple, as leaves can not satisfactorily maintain the high rate of assimilation that high temperatures allow. The facts of the case were clearly

[6] A collection of twenty cases, mostly from animal physiology, by Kanitz (*Zeits. für Elektrochemie*, 1907, p. 707), exhibits coefficients ranging from 1.7 to 3.3.

[7] *Landwirtschaftliche Jahrbücher*, Bd. XIX., 1890.

worked out by Miss Matthæi,[8] the rate of assimilation by cherry-laurel leaves being measured from — 6° C. to + 42° C. Up to 37° C. the curve rose at first gently and then more and more steeply, but on calculating out the values it is found that the acceleration for successive rises of 10° C. becomes less and less. Between 9° C. and 19° C. the increase is 2.1 times, the highest coefficient measured, and exactly the same coefficient as for respiration in this plant, which in itself is a striking point, seeing how different the processes are. The decrease of the coefficient with successive rises is a state of things which is quite general among non-vital reactions. A critical consideration of the matter leads one to the conclusion, however, that this failure to keep up the temperature acceleration is really due to secondary causes, as is also the appearance of an optimum at about 38° C. Some of these causes have been discussed by me elsewhere,[9] and I hope to bring a new aspect of the matter before the section in a separate communication. The conclusion formerly come to was that probably in its initial stages assimilation at these very high temperatures started at the full value indicated by a theoretically constant coefficient, but that the protoplasm was unable to keep up the velocity, and the rate declined. It must be borne in mind here that quite probably no chloroplast since the first appearance of green cells upon the earth had ever been called upon for anything like such a gastronomic effort as these cherry-laurel leaves in question. It is not to be wondered that their capacities speedily declined at such a banquet, and that the velocity-reaction of anabolic synthesis traces a falling curve in spite of the keeping up of all the factors concerned, to wit, temperature, illumination and supply of CO_2. This decline is not permanent, but after a period of darkening the power of assimilation returns. Physical-chemical parallels can easily be found among cases where the accumulation of the products of a reaction delays the apparent velocity of the reaction, but this complicated case may be left for further research.

In relation to assimilation, then, we must say that owing to secondary causes the case is not so clear over the whole range of temperature as that of respiration, but that at medium temperatures we have exactly the same relation between reaction-velocity and temperature.

We may consider now some data upon the combined net result of anabolic and katabolic processes. Such total effects are seen in their clearest form among unicellular saprophytic organisms for which we have a few data. Mlle. Maltaux and Professor Massart[10] have published a very interesting study of the rate of division of the colorless flagellate *Chilomonas paramœcium* and of the agents which they say stimulate its cell-division, in particular alcohol and heat.

They observed under the microscope the time that the actual process of division into two took at different temperatures. From 29 minutes at 15° C. the time diminished to 12 minutes at 25° C., and further to 5 minutes at 35° C. The velocities of the procedure at the three temperatures 10° C. apart will therefore be in the ratio of 1 : 2.4 : 5.76, which gives a factor of 2.4 for each rise of 10° C.

Now we are told by the investigators that at 35° C. Chilomonas is on the point of succumbing to the heat, so that the division rate increases right up to the death point, with no sign of an optimum effect.

[8] *Phil. Trans. Roy. Soc.*, Ser. B, Vol. CXCVII., 1904.

[9] "Optima and Limiting Factors," *Annals of Botany*, Vol. XIX., April, 1905.

[10] Maltaux and Massart, *Recueil de l'Institut botanique Bruxelles*, Tome VI., 1906.

Below 14° C. no observations are recorded.

Here, then, we have throughout the whole range exactly the same primary temperature relation exhibited by the protoplasmic procedure that we should expect for a chemical reaction in a test-tube.

This division phase is only a part of the life-cycle of the flagellate, and between division it swims about anabolizing the food material of the medium and growing to its full size ready for the next division. One wishes at once to know what is the effect of the temperature upon the length of the life-cycle. Is the whole rate of metabolism quickened in the same way as the particular section concerned with actual division? Of course a mobile flagellate can not be followed and its life-cycle directly timed, but the information was obtained by estimating carefully what percentage of individuals were in a state of actual division at each temperature. It was found that always 4 per cent. were dividing, whatever the temperature. This proves that the whole life-cycle is shortened in exactly the same proportion as the process of division at each temperature, and that it is just twenty-five times as long. Therefore, the life-cycle is 125 mins. at 35° C. and 725 mins. at 15° C., so that here, again, we have the physical-chemical relation with a factor of 2.4 for each rise of 10° C.

In this paper of Maltaux and Massart these relations are not considered as the manifestation of physical-chemical principles, but are regarded as reactions to stimuli; and the paper contains a number of experiments upon the effect of sudden changes of temperature upon the occurrence of division. As far as one can make out from inspection of the scattered literature, it does seem established that sudden changes of temperature act as stimuli in the strict sense of the word. In many investigations one finds it stated that a quick change of temperature produced a certain reaction which a slow change of temperature failed to evoke. Usually all the phenomena are treated in terms of stimulation, and the absence of reaction with slow change of temperature is regarded as secondary. Were it not for the specific stimulatory effects of quick change, which are not difficult to comprehend as a phenomenon *sui generis,* I hardly think so general a tacit acquiescence would have been extended by botanists to the view that all enduring changes of velocity of metabolism brought about by lasting changes of temperature are stimulatory in nature.

No determination of the rate of development of bacteria through a very wide range of temperature seems to have been made. There are various incidental experiments which indicate values about 2 for the coefficient of increase of metabolism for a rise of 10° C.

CONCLUSION

In this attempt to assert the inevitableness of the action of physical-chemical principles in the cell, I have not ventured upon even the rudiments of mathematical form, which would be required for a more precise inquiry. Bio-chemistry is indeed becoming added to the ever-increasing number of branches of knowledge of which Lord Bacon wrote:

> Many parts of nature can neither be invented with sufficient subtility, nor demonstrated with sufficient perspicuity, nor accommodated unto use with sufficient dexterity, without the aid and intervening of the mathematics.

To me it seems impossible to avoid regarding the fundamental processes of anabolism, katabolism, and growth as slow chemical reactions catalytically accelerated by protoplasm and inevitably accelerated by temperature. This soon follows if we once admit that the atoms and molecules

concerned possess the same essential properties during their brief sojourn in the living nexus as they do before and after.

In his address to the geological section, Professor John Joly, F.R.S., dealt with the effects of the presence of radium in the earth's crust and rocks on the distribution of the temperature gradients. By exhaustive determinations of the radium contents of various rocks and oceanic sediments, as well as by a systematic examination of the rocks of the Simplon and Central St. Gothard tunnels he found the change in temperature gradient observed to correspond exactly with the radium content of the rock. Space will not permit a proper abstract of this interesting address.

Leo Frank Guttman

THE OFFICIAL INSPECTION OF COMMODITIES

The adulteration of articles of commerce is distinctly an evil of civilization. In the primitive state of man, nature supplied directly to the consumer the materials for food and raiment. There was no commerce and, therefore, none of the attending frauds. The savage vented his evil nature in murder, rapine and other of the grosser forms of crime, but he had no opportunity to practise the more intellectual frauds which civilization has made possible.

As soon as commerce came into existence, merchants began to cheat in weight and measure and to practise other commercial frauds, but at first they had comparatively few opportunities for adulteration, as the articles exchanged were for the most part crude products, such as grain and wool, which could not be successfully imitated. It was at a later period, when flour, cloth and other adulterable articles were bought and sold, that sophistication began to be a serious menace to the public welfare, and the evil, having once gained a foothold, increased as civilization advanced.

In recent times adulteration has increased enormously, particularly during the past half century.

There are several reasons for this alarming growth of fraud. In the first place, the number of commercial articles which can be successfully imitated greatly increased during the past century and is still increasing. We have to-day on the market an endless variety of foods, drugs, paints, oils, chemicals and fabrics which can be readily debased by the addition of foreign materials, without having the fraud evident to the purchaser.

The second reason is that the manufacture of butter, lard, cheese, starch, yarn, cloth and other articles, which formerly was carried on in the household, has been transferred to the mill and the factory. It can not be disputed that the cost of production has been reduced by this centralization of labor, and the housewife, incidentally, has been saved a deal of hard work, but the genuineness of the products has suffered as a consequence.

Still another cause for the increase of sophistication in recent years is to be found in the variety of materials adapted for use as adulterants which are now obtainable. Some of the materials which are commonly used for fraudulent purposes are products of the highest scientific research. I will mention as examples—oleo oil, cotton-seed oil, stearine and petroleum products, used for mixing with higher-priced fats and oils; glucose syrup, the common adulterant for molasses; artificial vanillin and coumarin, used in vanilla extracts; salicylic acid, benzoic acid and other food preservatives; coal-tar dyes, which serve as a mask for other food adulterants; wood alcohol, acetanilid and other coal-tar products, also morphine, cocaine and other habit-forming